Science Performance of the Pupil-mapping Exoplanet Coronagraphic Observer (PECO)

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(1) What **is** PECO?

An Astrophysics Strategic Mission Concept Study, PECO is a space-based **telescope** + **coronagraph** that will take optical images + spectra of Earth-like exoplanets within the habitable zones (HZ) of nearby stars.

Telescope: 1.4-m D primary mirror

Coronagraph: Phase Induced Amplitude Apodization (PIAA)
- Inner working angle (IWA) ~2 λ/D
- High contrast + throughput at small IWAs
- Can image HZs with modest-sized telescope

Wavelengths: optical, 400—900 nm in 4 wide channels, further divided into ~16 narrow bands.

Orbit: heliocentric orbit, drifting away from Earth like Kepler and Spitzer.

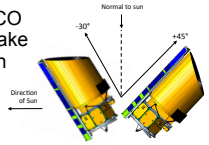


Figure 1: PECO spacecraft concept (LMT) with pointing constraints

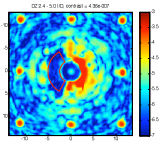


Figure 2: Talk by Rus Belikov on Thu 4/23. Recent NASA Ames lab results in air with PIAA lenses and MEMs DMs.

(2) What can PECO **detect** and **characterize**?

A primary goal: to detect and characterize **Earths** (1 R_E) and **Super-Earths** (2 R_E) within the HZs of nearby stars (< 20 pc).

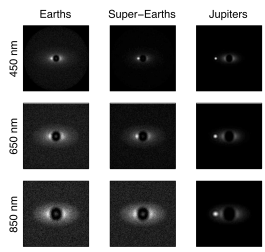


Figure 3: PECO's simulated performance detecting different types of planets around Tau Ceti (HIP 8012, 3.65 pc, G8.5 V, V=3.5, 1 zodi dust, 1.4-m D telescope, IWA 2.0 λ/D, 10-hr integration, photon noise added, coronagraphic throughput only).

PECO can easily characterize giant planets + exozodiacal dust disks (~40 pc).

Detect: image with SNR > 5.
Characterize: image many bands with SNR > 30

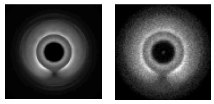


Figure 4: Initial PECO simulation of a dust disk with structure in it due to the existence of a planet (models from C. Stark for Sun at 3.3 pc with 1M_E planet at 3 AU, truncated inner edge, β = 0.0073, 500 nm integrated input flux density 3.16E-5 Jy, for comparison, DIRBE 1 zodi at 3.3 pc alone would have 1.58E-5 Jy).

"Grand Tour" for Earths and Super-Earths
Radial Velocity follow-up characterization
Snapshot Survey of Gas Giants + Dust Disks

(3) What will PECO's **spectral characterizations** tell us?

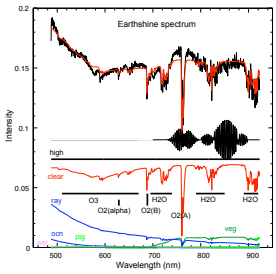
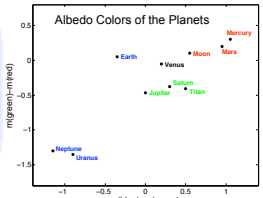


Figure 5: Observed reflectivity spectrum of Earth from Woolf et al. (2002). Black spectra, red model (CCD fringing packets subtracted). Note depth of O2 and H20 bands. Model has 7 component spectra, high cloud, clear atm, rayleigh, vegetation, subsurface ocean, aerosol, and pigment from phytoplankton.

PECO can measure coarse spectra, and differentiate between terrestrial, gas giant, and ice giant planets.



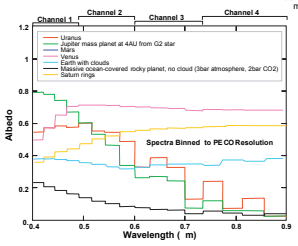


Figure 4: Relative albedo colors of planets in our solar system. Some differentiation between planet types can be made even with very coarse spectral information. (Traub, 2006)

Figure 6: Spectra of gas giant and terrestrial planets, binned to PECO's spectral resolution. (Guyon et al. 2006, several contributors)

(4) What are PECO's **mission goals**?

Detect Earth-like planets in HZs of nearby FGK stars and characterize orbits and w/spectra (e.g.H2O, O2, O3)

Characterize RV planets

Detect + characterize giant planets around 100+ stars w/spectra to constrain temps + compositions (e.g., CH4, H2O) and characterize exozodiacal dust distributions

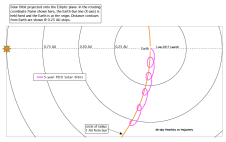


Figure 7: PECO in heliocentric Earth drift-away orbit (JPL)

Mission Phase	Initial Detection and Characterization				Follow-up High SNR Characterization				Total
	Number of Systems	Integration (hours each)	Overhead (hours each)	Visits (each)	Number of Systems	Integration (hours each)	Overhead (hours each)	Visits	(hours)
Commissioning	-	-	-	-	-	-	-	-	1,440
Grand Tour Earths + Super-Earths	20	16	8	10	5	400	200	2	10,800
Follow-up of Radial Velocity	15	16	8	3	15	200	100	2	10,080
Giant Planets + Disks Snapshot	120	16	8	1	-	-	-	-	2,880
							Total (hours)		25,200
							3-yr mission (hours)		26,280
							Margin (hours)		1,080

Table 1: An initial Design Reference Mission plan for PECO. Three mission phases meet the science goals. PECO-specific PIAA simulations provide integration time estimates to achieve SNR > 5 for detection and SNR > 30 for characterization. This design focuses on a specific group of targets with high completeness.

(5) How will PECO **achieve these goals** in 3 years?

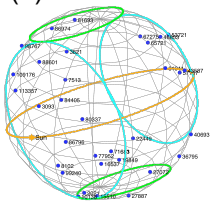


Figure 8: PECO-centric field of view for one moment in mission time. Sun/Earth avoidance and power-limited zones are outlined in blue. Continuous viewing zones are outlined in green. Grand Tour + RV targets are blue dots tagged with their HIP numbers.

PECO-specific PIAA simulations, including overhead for spacecraft time and factors for optical throughput, indicate that science goals are achievable in a 3-year mission.

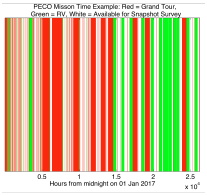


Figure 9: Total mission time allocation for one "roll of the dice" mission scenario (same as that in Fig. 10). Red are Grand Tour targets. Green are RV targets. White is available for Giant Planets + Snapshot Survey targets.

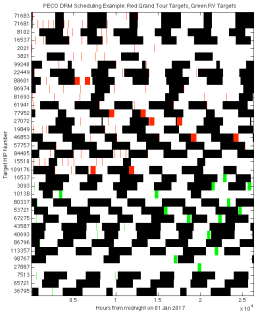


Figure 10: Example PECO mission scheduling. Mission time allocated for an example "roll of the dice" scenario. Red: Grand Tour targets. Green: RV targets. Black: targets not in PECO's allowed field of view. Thin red or green bands: detection attempts. Thick red or green bands: high-SNR characterizations after successful detection. White space: available time for Giant Planet + Disk Survey.

(6) Where can I **find out more** about PECO?

PECO at this meeting:
Wednesday, Session 4. Olivier Guyon: ASMCS-3: PECO PIAA and Coronagraphy at this meeting:
Thursday, Session 6, Ruslan Belikov: Demonstration Of The PIAA Coronagraph For Exoplanet Imaging At NASA Ames
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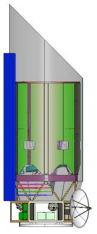

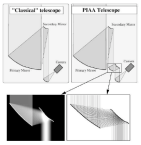

PECO Website:
http://caao.as.arizona.edu/PECO/